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ALLOCATING CHANNELS IN A COMMUNICATIONS SYSTEM

Claim To Priority

This application claims priority from German Application No. 19835643.9 and Patent Cooperation Treaty (PCT) Application No. PCT/DE99/02410.

Background

The invention relates to allocating channels in a communications system with (Code Division Multiple Access) CDMA subscriber separation.

In a communications system, a channel is a link from a message source (transmitter) to a message sink (receiver). The information to be transmitted is usually encoded, modulated and amplified at the transmitter. After transmission, which generally includes attenuation and distortion, the information is evaluated at the receiver using measurements that correspond to the transmitter.

Summary

In general, in one aspect, the invention is directed to allocating channels in a communications system in which code division multiple access (CDMA) codes are used to define channels between a transmitter and a receiver.

This aspect includes deriving a new CDMA code for a channel from other CDMA codes for other channels. The new CDMA code is derived based a tree structure that contains symbols that define the new CDMA code.

Other features and advantages of the invention will become apparent from the following description, including the claims and drawings.

Description of the Drawings

Fig. 1 shows a structure of orthogonal CDMA codes with a variable spread factor.

Fig. 2 shows a tree structure representing the CDMA codes.

Figs. 3 to 5 show allocation strategies for the allocation of channels.

Fig. 6 shows a schematic representation of a mobile radio system.

Description

Referring to Fig. 6, a radio communications system 10 is shown. In that system, information, such as voice, images and other data, is transmitted using electromagnetic waves. The information is transmitted over a radio frequency (RF) interface between transmitting and receiving radio stations (e.g.., a base station (BS) 12 and mobile stations (MS) 14, respectively). The

electromagnetic waves are emitted using carrier frequencies that lie in a frequency band provided for the communications system. Other frequencies, such as frequencies in the 2000 MHz frequency band (or thereabouts) are provided for future mobile radio systems with CDMA or time-divisioned (TD) CDMA transmission. An example of such a system is the UMTS (Universal Mobile Telecommunication System..

FDMA (frequency division multiple access), TDMA (time division multiple access), and/or CDMA (code division multiple access) subscriber separation are used to discriminate between signal sources (MS or BS), and thus to evaluate the signals. In CDMA subscriber separation, which is the subject of the process described herein, channels are distinguished using individual CDMA codes.

Channel allocation is a strategy for allocating frequency channels to individual links 16 so as to make best possible use of radio resources. In channel allocation, care is taken to ensure that resource (e.g., bandwidth) allocation to existing channels is as small as possible in order to accommodate future data rates. A resource expenditure arises if a CDMA code has to be removed from an existing link and a different CDMA code has to be allocated to the link.

In the process for allocating channels described herein, CDMA codes define channels for RF links. The CDMA

codes that are available for allocation to channels are derived from one another using a tree structure (see, e.g., Fig. 2, described below). The CDMA codes are represented by nodes within the tree structure. In the tree structure, a chip sequence (e.g., 1110) of a higher order CDMA code is a subset of a chip sequence of a lower order CDMA code. In one node, a plurality of branches converge and, in turn, lead to further lower order nodes.

The nodes in the channel allocation process use sequences of symbols for the chip sequence, in this embodiment, ones and zeros. The sequences of symbols for two nodes differ at a position that corresponds to the distance between the two nodes and their joining node within the tree structure. A small difference in position means that two nodes differ significantly. This is true when the difference occurs near to the root of the tree structure. In other words, the joining node (parent node) is near to the root of the tree in this case.

Free nodes (i.e., unassigned nodes) and assigned nodes are distinguished. A free node designates a non-assigned (i.e., free) CDMA code and an assigned node designates an assigned CDMA code. Only non-assigned CDMA codes can be allocated to an RF link/channel.

To allocate a free CDMA code to a link, free nodes are selected, which are not connected to an already-occupied node directly in an upward or downward direction

in the tree structure. In this embodiment, free nodes that differ from an already occupied node by at least one symbol are selected. It is noted that it is not permissible to allocate a CDMA code whose chip sequence is a precise subset of a CDMA code that has already been assigned or whose chip sequence forms a subset of a previously-assigned chip sequence.

The position in the sequence of symbols at which a difference from an already occupied node occurs is determined for selected nodes starting, in each case, at the root of the tree structure. The position is a measure of the discriminating (i.e., differentiating) "power" of the two CDMA codes. This power is the ability of the codes to differentiate channels. If two CDMA codes differ significantly, the data rate in two channels can be increased for one of the CDMA codes without risking a collision with the second CDMA code.

In the subject allocation strategy/process, a sum of positions of nodes in the tree structure is determined for all of the assigned nodes. A channel with the CDMA code that corresponds to the node having a predefined sum is allocated. The allocation strategy is thus related to the discriminating power with respect to all the other CDMA codes, i.e., to a sum of instances of discrimination.

The tree structure is such that the distance between a node and a root node corresponds to an increase in a

spread factor of the CDMA code, and thus directly to a reduction in the data rate for the link defined by that code. The data rate can be increased without allocating other CDMA codes by changing a CDMA code. This is done by removing an existing node and allocating a new node to the tree structure. The new node branches off from the existing node in the direction of the root.

One advantage of the foregoing allocation strategy/process is that the predefined sum may be relatively small. This ensures that the CDMA codes differ greatly. This, in turn, leaves open the possibility that the data rate for the link with the newly-allocated CDMA code can be increased in the future without significantly affecting the rest of the allocation process.

The objective is different if no increase, or only a limited increase, in the data rate is possible or desired for a large number of connections. This is the case, e.g., for subscribers with a fixed basic data rate. Here, it is usually better if the predefined sum is maximized. CDMA codes which do not differ greatly are thus assigned. That is, parts of the tree structure are kept free for further links with higher data rates.

A mixed form of the previous two processes enables the data rate of a link to be increased, and a node with a difference from an already assigned node at a specific position to be selected. The possibility of increasing

the data rate is expressed in the tree structure in a number of nodes that can be displaced in the direction of the root (a node before the joining node with an already occupied node) without a collision occurring with a CDMA code that has already been assigned. If the increase possibility is known in advance, a part of the tree structure that is just sufficient, i.e. not too much and not too little, can be reserved.

The process can also be implemented in multiple stages. Thus, a plurality of channels with different CDMA codes can be allocated. A desired data rate results from the totality of the individual data rates of the CDMA codes. The free nodes of the tree structure can nevertheless be utilized with a high utilization rate, i.e. occupancy of the nodes.

For digital systems that are widespread, the symbols are digital values. From each node, a branch branches off in the direction of the root and two branches branch off in the opposite direction. A mapping of the CDMA codes onto the tree structure includes two following nodes of outgoing branches to be mapped, starting from the root of the tree structure using an additional "0" or "1" in the sequence of symbols.

The CDMA codes are, for example, orthogonal codes with a variable spread factor (Orthogonal Variable Spreading Factor - OVSF). As a result, detection at the

receiver is made easier because such CDMA codes continuously support optimum decorrelation.

Although a channel assignment system according to the invention can be used in a very wide variety of communications systems, use in the downward direction (from MS to BS in Fig. 6) of a radio interface in a broadband radio communications system is particularly advantageous. Such a radio interface is designed for a third mobile radio generation and can support a large number of channels. The more channels, the more important it is to have a good assignment strategy.

A desired data rate and/or increased possibility for a data rate of the link is derived from an identifier and/or from a signaled request of a mobile station (MS). The increased possibility can thus be determined precisely for the mobile stations, in accordance with the current link and service profiles therefor. As a result, only free spaces in the tree structure that are necessary and useful are reserved in the assignment strategy.

An example of a communications system in which the channel assignment process described herein may be use is a digital radio communications system with broadband channels, such as that described in "UTRA Physical Layer Description FDD parts", volume 4 (dated June 25, 1998). In that system, like other systems with CDMA subscriber

separation, different links can be distinguished using an individual CDMA code to spread the signals.

For the downlink direction, i.e., RF transmission from BS 12 to MS 14, the codes of Fig. 1 may be used. These codes are orthogonal codes with a variable spread factor (OVSF) and a fixed chip rate of 4.096 MCPS. The orthogonal codes are represented in the tree structure of Fig. 1 with individual CDMA codes being derived from other CDMA codes in the tree structure.

From one level of the tree to another level, the number of chips per CDMA code, and thus the spread factor (SF), doubles. Starting from the CDMA code with the chip sequence (1, 1) two CDMA codes of the next lowest level (1, 1, 1, 1) and (1, 1, -1, -1) are derived. The first half (1, 1) of the upper level code is used for the new, lower-level code and the second half the same (1, 1) or an inverted form (-1, -1) of the upper level code. This produces a code family over, e.g., eight levels.

Within the eight levels, there are 508 different CDMA codes with eight different data rates (2048 Kilobit per second (Kbit/s) with SF = 4, 1024 Kbit/s with SF = 8, 512 Kbit/s with SF = 16, 256 Kbit/s with SF = 32, 128 Kbit/s with SF = 64, 64 Kbit/s with SF = 128, 32 Kbit/s with SF = 256). For example, a 32 Kbit/s gross data rate is needed to encode voice information with an

8 Kbit/s net data rate and to transmit the voice information via the radio interface with error protection.

Within the level with a spread factor SF = 256, there are 256 different CDMA codes and, at the next highest level, there are 128 CDMA codes, etc. The CDMA codes are allocated in accordance with a data rate (i.e., bandwidth) required by the link/channel. If all the CDMA codes are still free, e.g., during the run-up phase, one of the CDMA codes can be allocated at random. However, if some of the CDMA codes have already been assigned, peripheral conditions have to be taken into account in the allocation of a free CDMA code to a new link.

The CDMA codes that are used within a frequency band in a radio cell differ in at least in part of their chip sequence. Furthermore, changes in the data rate of a link can be permitted in a predictive fashion. CDMA codes of a higher level should not be blocked by a new allocation of a lower-level CDMA code.

Thus, for orthogonal codes with a variable spread factor (OVSF), a structure according to Fig. 2, which designates the nodes of the tree with a digital signal sequence, is selected. Starting from a node, for example 11, a "1" is added for the upper branch in the direction away from the root, and a "0" is added for the lower branch. This simplifies evaluation of the tree structure because the number of positions in the sequence of symbols

corresponds directly to the level of the node (and of the spread factor SF) in the tree structure.

To make a comparison of nodes, which may be necessary in the processes explained below, the position of departure should be the root 18 of the tree structure. However, an inverse evaluation may also be performed, i.e., one that starts at the branches the tree.

If, for example, nodes 1110 and 1101 are compared with each other, a difference occurs at the third position from the left (i.e., 1110 and 1101). Later differences are not of interest. For 10 and 1101, it is the second position. In an extreme case, the difference occurs at the eighth position (compare 11111110 and 11111111). The comparison is thus left-aligned.

If, for example, two nodes 00 and 001 are compared with one another, no difference can be determined. The two nodes do not differ by at least in one symbol. If no difference is found, it is an indication that two CDMA codes are directly connected to one another in the upward or downward direction of the tree structure.

For the allocation of a CDMA code, all of the nodes that have no difference (i.e., the hamming distance is equal to 0) in comparison with an assigned node should be excluded. In other words, a node (1111 in Fig. 3) blocks all of the nodes (111, 11, 11, 1) arranged in ascending

order in the tree, and vice versa. That is, these CDMA codes should not be used to define channels.

For channel allocation, all of the nodes are different from previously-assigned nodes are selected. Furthermore, those nodes that correspond to the desired data rate are considered. As shown in Fig. 3, three nodes (101, 010, 001) are available for a desired data rate of 1024 Kbit/s with SF = 8. A selection may be made between these nodes since they are for the desired data rate.

For this purpose, in each case, the sum of the positions at which, in comparison with all the already assigned nodes (at least all of the assigned nodes of part of the tree structure), the first difference from the left has occurred is used for these three nodes 101, 010, 001. For node 101, the sum is 9 = 2 + 2 + 3 + 1 + 1, for node 010 the sum is 8 = 1 + 1 + 1 + 2 + 3, and for node 001 the sum is 8 = 1 + 1 + 1 + 2 + 3.

The sums are then compared with a predefined sum, which may be set beforehand. If the predefined sum is the maximum of the sums, the node 101 is selected. If the predefined sum is the minimum of the sums, the node 010 or 001 can be selected. The selection between the remaining two nodes 010 or 001 is made randomly.

The maximum is selected if it is desired to group the occupied nodes, i.e. the allocated CDMA codes, closely to one another (as shown, e.g., Fig. 4). This has advantages

if great changes are not to be expected in the data rates of the links. The minimum is selected in order to achieve the most uniform possible distribution of all the CDMA codes used in the tree. This has, in statistical terms, the advantage that it provides a maximum degree of flexibility for a later assignment of higher data rates. According to Fig. 3, the benefit of this is not yet felt because it is not possible to simply double the data rate for any of the nodes 101, 010 or 001. However, the links are not permanent, so that when a previously occupied CDMA code is released, the probability of an increase in the data rate being possible in the future is greater for nodes 010 and 001 than for the node 110.

Fig. 4 shows links to subscribers with a basic data rate of 32 Kbit/s, e.g., simple voice links. Increases in the data rate are not expected for these subscribers. So, the strategy of using the maximum for the predefined sum is selected. The sum for the free node 11111101 is 34 = 7 + 7 + 8 + 6 + 6 and for the nodes 11111001 and 11111000 is the sum 32 = 6 + 6 + 6 + 7 + 7. Accordingly, node 11111101 is selected. A later new allocation of the node 1111100 with a higher data rate of 64 Kbit/s is therefore not prevented.

An additional aspect for both strategies arises if not only the desired data rate is used for the link but also a defined increased possibility for the data rate is

known. The desired data rate and/or increased possibility for a data rate of the link is derived from an identifier (for example a service class of the possible services or an identification of the mobile station) or from a signaled request of a mobile station for a service. These values can also be updated in the course of a link.

The optimization of the allocation is directed at a window of data rates for a link. In Fig. 5, in turn, some of the nodes are already assigned. The intention is to show the allocation of a CDMA code for a link with a data rate of 32 Kbit/s with a possibility of increase to a maximum of 64 Kbit/s. A node with a difference from an already assigned node is selected precisely at a specific position that corresponds to the increase possibility. The possibility of increase to 64 Kbit/s corresponds to the seventh position.

This is the case for the nodes 11111001 or 11111000 and 11110011 or 11110010, respectively. The difference between these nodes and the nodes 11111010 and 11110000 occurs precisely at the seventh position (underlined). Other free nodes already have differences at the sixth position (11110100) or not until the eighth position (11111111). Which of the two node pairs (11111001 or 11111000 and 11110011 or 111110010, respectively) will be shortlisted depends again on the optimization to the maximum or minimum. The selection between 11111001 or

11111000 and 11110011 or 11110010, respectively, is random here. It is again noted that the possibility of increasing the data rate should also be taken into account for already existing links. If a possibility of increase to 128 Kbit/s has been noted in advance for the link of the node 11110000, this is an exclusion criterion for the nodes 11110011 and 11110010.

If, for example, a link is to be operated with a data rate of 96 Kbit/s, two CDMA codes are to be assigned. More specifically, either three 32 Kbit/s codes are assigned or one for 32 Kbit/s and a further for 64 Kbit/s. The allocation method is thus a multi-stage method. The desired data rate results from the totality of the individual data rates of the CDMA codes.

In Fig. 5. the foregoing means, for example, that depending on the optimization criterion one of the nodes 1111011, 1111010 or 1111001 is assigned for the 64 Kbit/s, and subsequently a remaining free node is selected for 32 Kbit/s. The allocation of a CDMA code for the higher data rate should take place before the allocation of a CDMA code for the lower data rate.

The mobile radio system illustrated in Fig. 6 is an example of a radio communications system is comprised of mobile switching centers (MSC) 20 which are interlinked to one another and/or constitute the access to a fixed network PSTN 22. Furthermore, these mobile switching

centers MSC 20 are connected to in each case at least one device radio network controller (RCN) 24 for radio resource management. Each of these devices in turn is linked to at least one base station (BS) 12.

A base station can set up, via a radio interface, a link to further radio stations, for example mobile stations or other mobile and fixed terminals. Fig. 6 also shows links V1, V2, Vk for transmitting useful information and signaling information between mobile stations MS and a base station BS. An operations and maintenance center (OMC) 26 performs monitoring and maintenance functions for the mobile radio system and for parts thereof.

Base station 12 contains a storage device (SP) 28 (e.g., a memory) for storing the tree structure, the occupied nodes and the CDMA codes, as well as a program for carrying out the allocation method and a processing device (BE) 30 (e.g., a microprocessor) for selecting a non-occupied node with corresponding CDMA code and for assigning a channel with the CDMA code to a link in accordance with one of the previous strategies.

The tree-structure coding processes described herein are not limited to use on the hardware (i.e., base station and mobile station) of Fig. 6; they may find applicability in any computing or processing environment and with any type of machine that is capable of running machine-readable instructions, such as a computer program. The

processes may be implemented in hardware, software, or a combination of the two.

The processes may be implemented in computer programs executing on programmable computers that each include a processor, a storage medium readable by the processor (including volatile and non-volatile memory and/or storage elements), at least one input device, and one or more output devices. Program code may be applied to data entered using an input device (e.g., a mouse or keyboard) to perform the coding processes and to generate output information.

Each such program may be implemented in a high level procedural or object-oriented programming language to communicate with a computer system. However, the programs can be implemented in assembly or machine language. The language may be a compiled or an interpreted language.

Each computer program may be stored on a storage medium or device (e.g., CD-ROM, hard disk, or magnetic diskette) that is readable by a general or special purpose programmable computer for configuring and operating the computer when the storage medium or device is read by the computer to perform the coding processes. The coding processes may also be implemented as a computer-readable storage medium, configured with a computer program, where, upon execution, instructions in the computer program cause the computer to operate in accordance with the process.

Other embodiments not described herein are also included in the scope of the following claims.

What is claimed is: